SCORBOT-ER 9Pro

User Manual

Catalog # 200034 Rev. B

intelitek

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SCORBOT-ER 9Pro

Catalog # 200034 Rev. B

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Safety

The SCORBOT-ER 9Pro is a potentially dangerous machine. Safety during operation is of the utmost importance. Use extreme caution when working with the robot.

Precautions

The following chapters of this manual provide complete details for proper installation and operation of the SCORBOT-ER 9Pro. The list below summarizes the most important safety measures.

1. Define a safety area as detailed on Figure 4-1.
2. Make sure the robot base is properly and securely bolted in place.
3. Make sure the cable from the body to the base can move freely during all movements of the robot's base axis.
4. Make sure both the encoder cable and the robot power cable are properly connected to the controller before it is turned on.
5. Make sure the robot arm has ample space in which to operate freely.
6. Make sure a guardrail or rope has been set up around the SCORBOT-ER 9Pro operating area to protect both the operator and bystanders.
7. If the distance between the robot and the Controller is greater than 1.5m, ensure that an EMERGENCY button is easily accessible, either with an external EMERGENCY button, or from the Teach Pendant.
8. Do not enter the robot's safety range or touch the robot when the system is in operation.
9. Press the controller's EMERGENCY button before you enter the robot's operating area.
10. Turn off the controller's POWER switch before you connect any inputs or outputs to the controller.

☞ *To immediately abort all running programs and stop all axes of motion, do one of the following:*

- Press the red EMERGENCY button on the controller.
- Press the EMERGENCY button on the Teach Pendant.

Warnings

1. Do not operate the SCORBOT-ER 9Pro until you have thoroughly studied this User Manual and the Controller USB-Pro and Scorbase for ER 9Pro/ER 14Pro User Manuals. Be sure you follow the safety guidelines outlined for both the robot and the controller.
2. Do not install or operate the SCORBOT-ER 9Pro under any of the following conditions:
   - Where the ambient temperature drops below or exceeds the specified limits.
   - Where exposed to large amounts of dust, dirt, salt, iron powder, or similar substances.
   - Where subject to vibrations or shocks.
   - Where exposed to direct sunlight.
   - Where subject to chemical, oil or water splashes.
   - Where corrosive or flammable gas is present.
   - Where the power line contains voltage spikes, or near any equipment which generates large electrical noises.
3. Do not abuse the robot arm:
   - Do not operate the robot arm if the encoder cable is not connected to the controller.
   - Do not overload the robot arm. The combined weight of the workload and gripper may not exceed 2kg (4.4 lb). It is recommended that the workload be grasped at its center of gravity.
   - Do not use physical force to move or stop any part of the robot arm.
   - Do not drive the robot arm into any object or physical obstacle.
   - Do not leave a loaded arm extended for more than a few minutes.
   - Do not leave any of the axes under mechanical strain for any length of time. Especially, do not leave the gripper grasping an object indefinitely.

The Scorbot robot is dangerous and can cause severe injury.

Use with extreme caution.

Set up a protective screen or guardrail around the robot to keep people away from its working range.

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1

Unpacking and Handling

This chapter contains important instructions for unpacking and inspecting the SCORBOT-ER 9Pro robot arm.

☞ *Read this chapter carefully before you unpack the SCORBOT-ER 9Pro robot and controller.*

Unpacking the Robot

The robot is packed in expanded foam, as shown in Figure 1-1.

To protect the robot during shipment, a metal plate holds the gripper- mounting flange to the robot base. The plate is fixed to the flange with three bolts and to the base with two bolts. Use a 3mm hex socket wrench to detach these bolts.

Save these bolts and the plate. You will need them should you repack the robot for shipment.

Save the original packing materials and shipping carton. You may need them later for shipment or for storage of the robot.

Figure 1-1: SCORBOT-ER 9Pro in packing

Handling Instructions

The robot arm weighs 53.5 kg (117.7 lb). Two people are needed to lift or move it.

Lift and carry the robot arm by grasping its body and/or base. Do not lift or carry the robot arm by its upper arm or forearm.

Acceptance Inspection

After removing the robot arm from the shipping carton, examine it for signs of shipping damage. If any damage is evident, do not install or operate the robot. Notify your freight carrier and begin appropriate claims procedures.

The following items are standard components in the SCORBOT-ER 9Pro package. Make sure you have received all the items listed on the shipment's packing list. If anything is missing, contact your supplier.

Table 1-1: SCORBOT-ER 9Pro Items.

Item	Description
SCORBOT-ER 9Pro Robot Arm	Includes: Cabling; Hardware for mounting robot: 3 M8x60 bolts; 3 M8 washers; 3 M8 nuts. (Optional air hoses included).
Gripper (Optional): 2 options	Pneumatic Gripper includes: Pneumatic solenoid valve; Hardware for mounting gripper: 4 4M4x10 screws.
	Electric DC Servo Gripper with encoder includes: Hardware for mounting gripper: 4 4Mx10 screws.
Controller USB-Pro	Includes: Power Cable; USB Cable. TP By-Pass Plug (required when TP not connected) (Preinstalled on the Controller). External Emergency By-Pass Plug (Preinstalled on the Controller.
Teach Pendant (Optional):	Includes: Teach Pedant – USB-Pro controller cable; Mounting fixture; Teach Pendant for Controller USB and USB-Pro User Manual
Software	Scorbase for ER 9Pro/ER 14Pro
Documentation	Controller USB-Pro User Manual
	Robocell for ER 9Pro/ER 14Pro User Manual
	Scorbase for ER 9Pro/ER 14Pro User Manual
	SCORBOT-ER 9Pro User Manual

Repacking for Shipment

Be sure all parts are back in place before packing the robot.

When repacking the robot for shipping, bolt **the flange and base to the metal plate.** Failure to do so may result in irreversible damage to the arm, particularly to the Harmonic Drive transmissions. Also be sure to secure the cables around the foam spool.

The robot should be repacked in its original packaging for transport.

If the original carton is not available, wrap the robot in plastic or heavy paper. Put the wrapped robot in a strong cardboard box at least 15cm (about 6inches) longer in all three dimensions than the robot. Fill the box equally around the unit with resilient packing material (shredded paper, bubble pack, expanded foam chunks).

Seal the carton with sealing or strapping tape. Do not use cellophane or masking tape.

2

Specifications

The following table gives the specifications of the SCORBOT-ER 9Pro**.**

Table 2-1: Specifications.

Robot Arm Specifications	
Mechanical Structure	Vertical articulated, enclosed casting
Number of Axes	5 plus gripper
Axis Range	• Axis 1: Base rotation: 270° • Axis 2: Shoulder rotation: 145° • Axis 3: Elbow rotation: 210° • Axis 4: Wrist pitch: 196° • Axis 5: Wrist roll: 737°
Speed: Effective Speed, Maximum Speed	• Axis 1: Base rotation — 80°/sec, 140°/sec • Axis 2: Shoulder rotation — 69°/sec, 123°/sec • Axis 3: Elbow rotation — 77°/sec, 140°/sec • Axis 4: Wrist pitch — 103°/sec, 166°/sec • Axis 5: Wrist roll — 175°/sec, 300°/sec
Maximum Operating Radius	691mm (27.2") without gripper
End Effector: options:	Pneumatic Gripper
	Electric DC Servo Gripper
Homing	Optical switch and encoder index pulse on each axis
Feedback	Incremental optical encoders with index pulse on each axis
Actuators	24VDC servo motor on each axis
Transmission	Harmonic Drive gears and timing belts
Maximum Payload	•5kg (11 lb) (with reduced acceleration) •2kg (4.4 lb) (Full speed) (including gripper)
Position Repeatability	±0.05mm (0.002")
Weight	53.5 kg (117.7 lb)
Ambient Operating Temperature	2° - 40°C (36° - 104°F)

Structure

The SCORBOT-ER 9Pro is a vertical articulated robot, with five revolute joints. With gripper attached, the robot has five degrees of freedom. This design permits the end effector to be positioned and oriented arbitrarily within a large workspace.

Figures 2-1 and 2-2 identify the joints and links of the mechanical arm.

Each joint is driven by a permanent magnet DC motor via a Harmonic Drive gear transmission and timing belt.

The movements of the joints are described in the following table:

Table 2-3: Joint Movements.

Axis No.	Joint Name	Motion	Motor No.
1	Base	Rotates the body	1
2	Shoulder	Raises and lowers the upper arm.	2
3	Elbow	Raises and lowers the forearm.	3
4	Wrist Pitch	Raises and lowers the end effector.	4
5	Wrist Roll	Rotates the end effector.	5

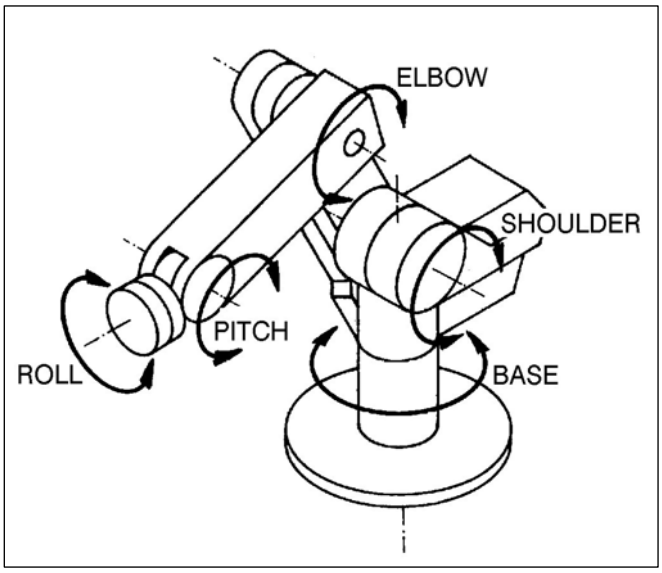

Figure 2-1: SCORBOT-ER 9Pro Joints

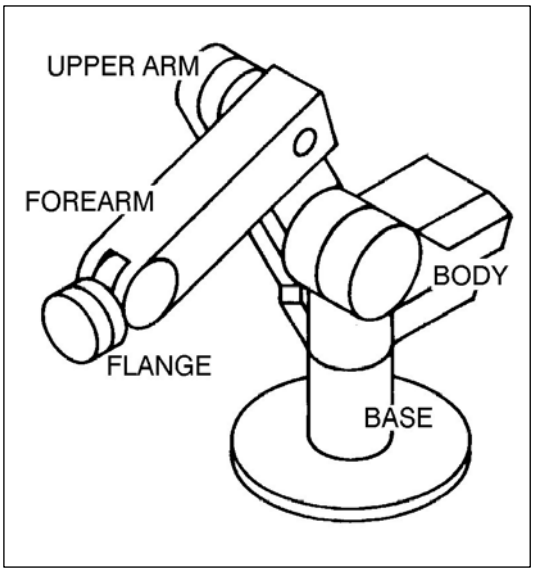

Figure 2-2: SCORBOT-ER 9Pro Links

Work Envelope

The length of the links and the degree of rotation of the joints determine the robot's work envelope. Figure 2-3 shows the dimensions and reach of the SCORBOT-ER 9Pro, while Figure 2-4 gives a top view of the robot's work envelope.

The base of the robot is normally fixed to a stationary work surface. It may, however, be attached to a slidebase, resulting in an extended working range.

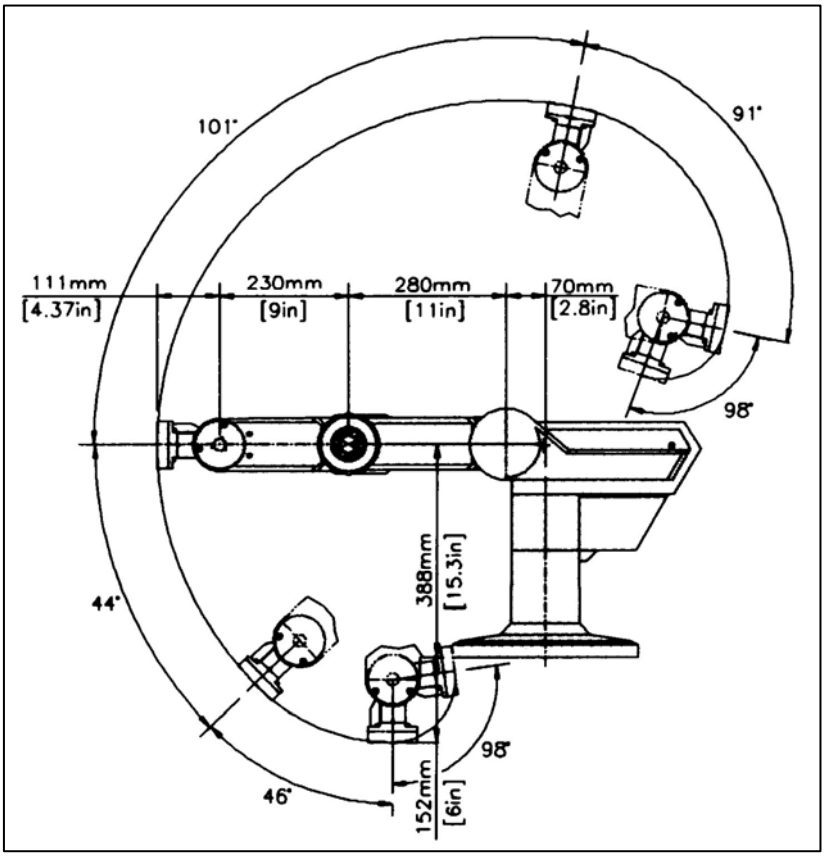

Figure 2-3: Operating Range (Side View)

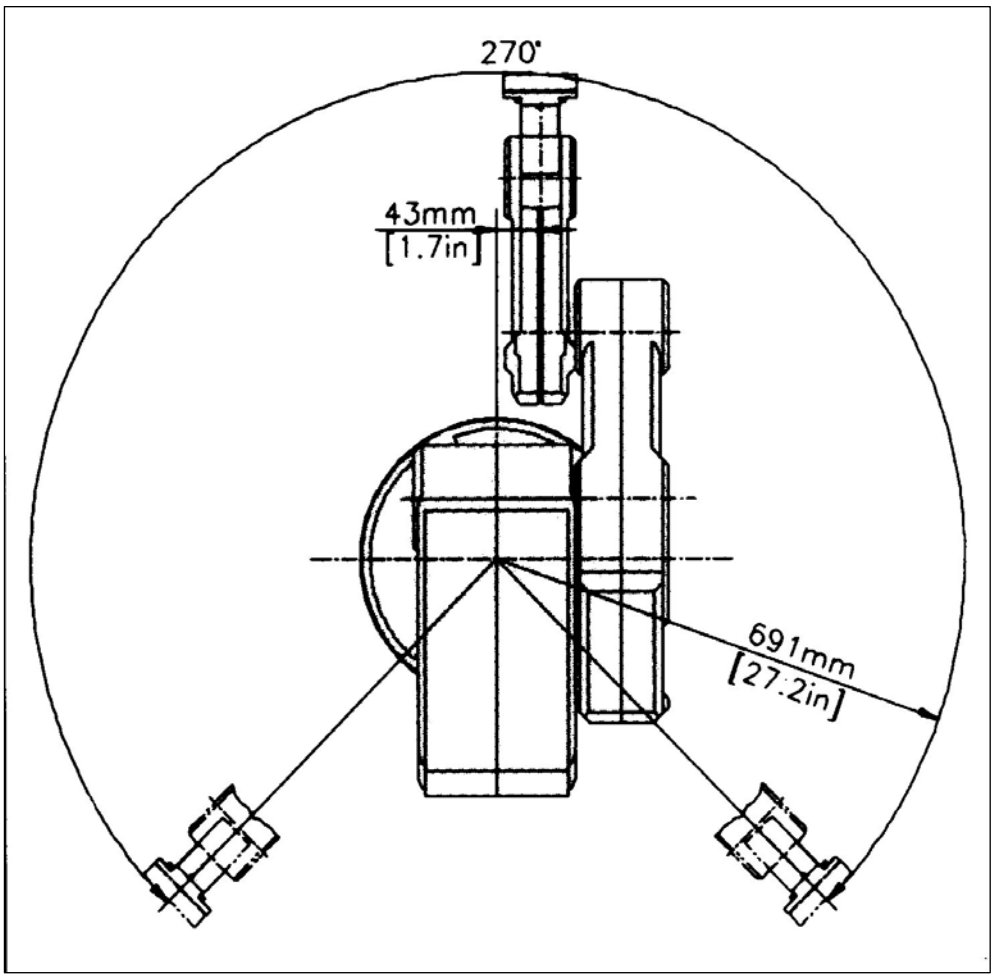

Figure 2-4: Operating Range (Top View)

3

Installation

Preparations

Before you make any cable connections, set up the system components according to the following Preparation instructions.

Controller and Computer/Terminal Setup

Place the controller and computer at a safe distance from the robot well outside the robot's safety range.

Make sure the setup complies with the guidelines defined in the Safety chapter, in the Controller USB-Pro User Manual.

Robot Setup

Refer to Figures 4-1, 4-2 and 4-3.

1. Set up the SCORBOT-ER 9Pro on a sturdy surface with at least one meter of free space all around the robot.

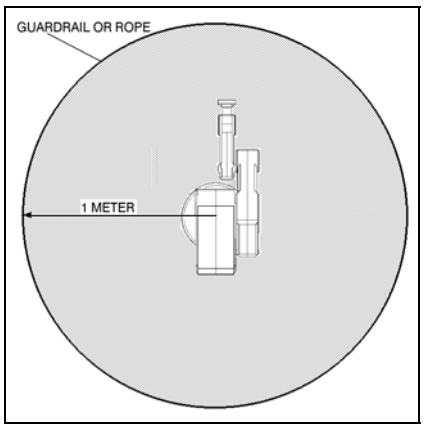

Figure 4-1 Robot Safety Range

2. Note that the robot cable clamp is located at the midpoint of the robot's horizontal range. Using this midpoint as a reference, set up the robot so that it faces in the proper direction towards the application or machine it will serve.
3. Fasten the base of the robot to the work surface with three sets of M8 bolt, washer and nut.

   Make sure the robot is securely bolted in place. Otherwise the robot could become unbalanced and topple over while in motion.
4. Grasp the robot body and turn the robot to each extreme of its base axis.

☞ *Make sure the segment of cable from the body to the base is not obstructed, and/or cannot become caught under a corner of the robot's platform or work surface during all movements of the base axis.*

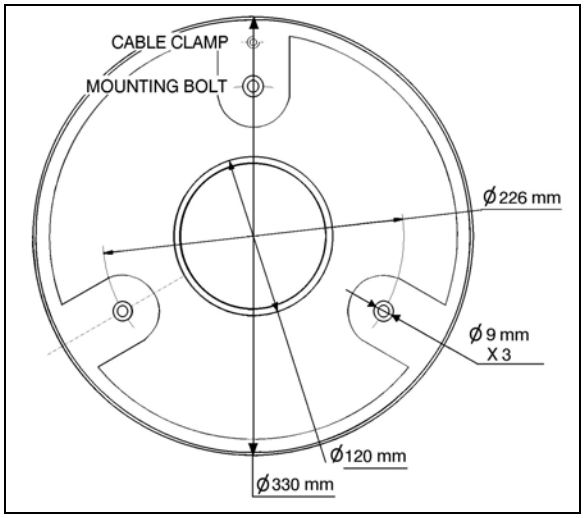

Figure 4-2: Robot Base Layout

Make sure the robot is mounted on a surface large enough to provide support for this segment of the robot cable during all movements of the base axis.

5. Set up a guardrail or rope around the SCORBOT-ER 9Pro operating area to protect both the operator and bystanders.

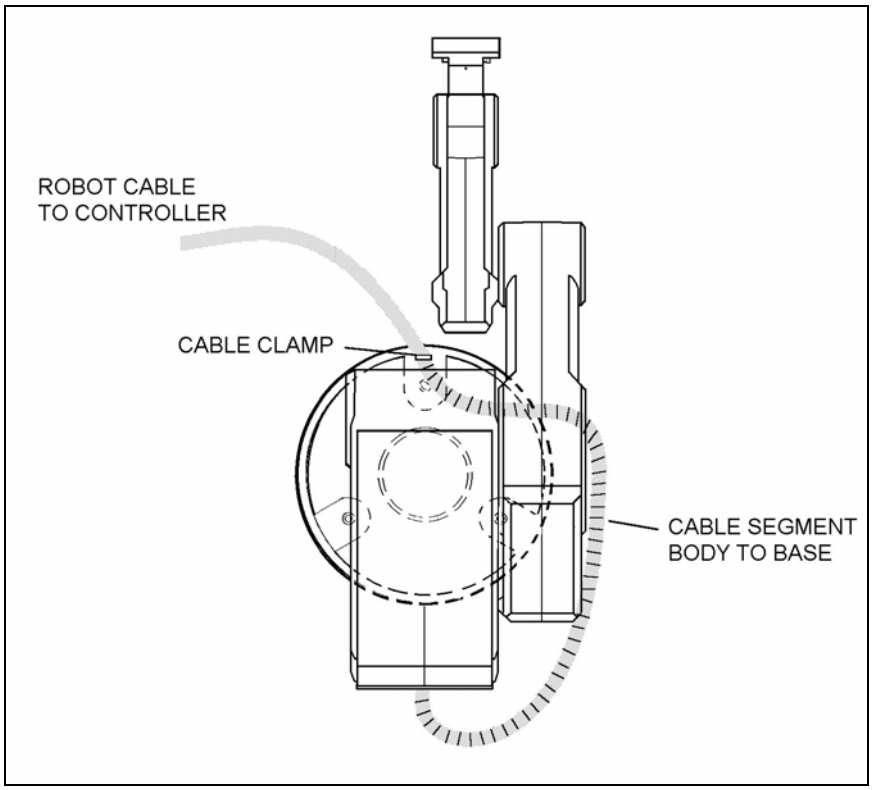

Figure 4-3: Robot Setup

SCORBOT-ER 9Pro Installation

Controller Installation

Perform the necessary installation and configuration procedures detailed in the Controller USB-Pro User Manual.

Robot Installation

☞ *Before you begin, make sure the controller POWER switch is turned off.*

The robot cable has a number of connectors. Connect them to the controller according to following three steps. Refer to Figure 4-4.

1. Connect the green/yellow wire to the Safety Ground: Unscrew and remove the ground nut and washer from the Safety Ground stud. Place the ground wire terminal onto the stud, then replace and tighten the washer and nut.
2. Plug the D37 connector into the Robot Encoders port. Tighten the retaining screws on the connector.
3. Plug the D50 connector into the Robot motors port. Tighten the retaining screws on the connector.

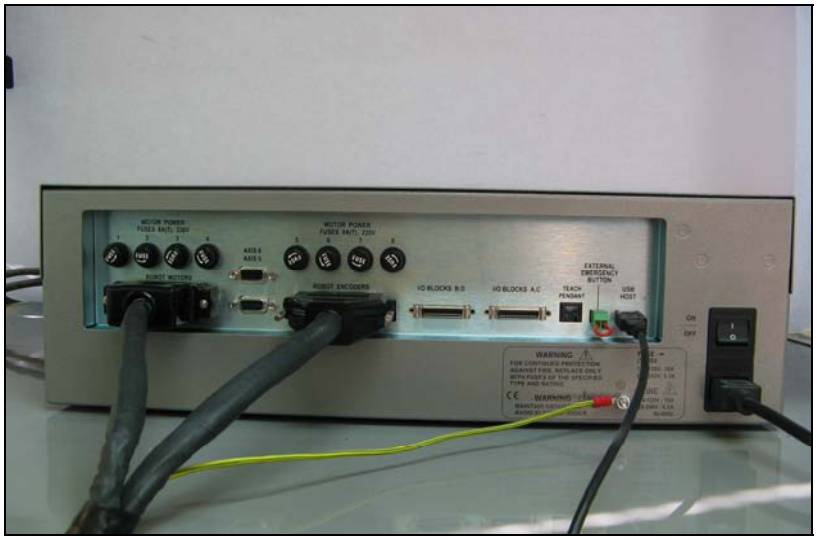

Figure 4-4: Robot-Controller - Back

☞ *Before you begin, make sure the controller POWER switch is turned off.*

☞ When disconnecting the robot from the controller, do it in the reverse order; that is:

- Disconnect the D50 Robot Power connector.
- Disconnect the D37 Encoders connector.
- Disconnect the ground wire.

Hardware check

☞ *Check that all the wires are correctly installed. See Figure 4-4.*

Having installed the hardware, it is necessary to perform a check to see that the hardware is working correctly. This is performed as follows:

1. Turn on the controller. Turn on the computer. Start Scorbase.
2. Select **Options | On Line,** decline the option to turn control on.
3. Select **View | Dialog Bars | Encoder Counts.**
4. Manually move each axis separately while watching the **Encoder Counts** window. As each axis is moved, the numbers pertaining to it should change. Should all the numbers change for all of the axes, this indicates that the robot is functioning and communicating with the controller.
5. Press **F5** to turn control on.

   Select **View | Manual Movement.** Control each axis with the relevant buttons. Watch the **Encoder Counts** window to see that it is responding correctly.

☞ *It is important to make sure that one has the emergency stop button on the controller within easy reach as the SCORBOT-ER 9Pro could behave unexpectedly.*

Homing the Robot

After you have completed the robot installation, execute the robot's Home routine, as described below.

☞ *The robot must be homed before you mount the gripper.*

Before you begin the homing procedure, make sure the robot has ample space in which to move freely and extend its arm.

1. Turn on the controller. Turn on the computer. Start Scorbase.
2. Select **Run | Search home - all axes**.

   OR

   click the **Search Home** icon.

A window opens displaying the number of the axis currently being homed. Each time an axis is successfully homed, a checkmark appears next to the axis number. After the five axes and the gripper have been homed, a checkmark appears next to Robot.

Figure 4-5: Homing Status Window

To abort homing while the procedure is still in progress, do one of the following:

- Press [F9] (Stop command)
- Press the red EMERGENCY button on the controller.
- Press the EMERGENCY button on the Teach Pendant.

If the homing procedure fails, a message appears.

The **Search Home - All Axes** command executes the robot's homing procedure as well as that of any peripheral devices that have been configured in the **Options | Hardware Setup** menu. The command is available only when Scorbase is On-line for the first time.

If the system has already been homed and you change Scorbase to Off-line mode, there is no need to home the system again when you return to On-line mode.

When Scorbase is in Off-Line Mode, or when Robocell is installed, the homing procedure is not required, although it can be executed.

Peripheral installation

For all peripherals, once they have been physically installed they must be added in Scorbase. Make sure USB-Pro controller servo control is off. The Motors state indicator on the front panel of the controller must be in Off state (unlit). Select **Options | Hardware Setup** and select the peripheral that has been added.

Gripper Installation

The gripper is attached to the flange at the end of the robot arm whose layout is shown in Figure 4-6.

Pneumatic Gripper

The pneumatic gripper, shown in Figure 4-7, is controlled by a 4/2 solenoid pneumatic valve which is activated by one of the controller's relay outputs. The valve is 24VDC and can draw its power from the controller's User Power Supply.

☞ *The robot must be homed before you mount the gripper.*

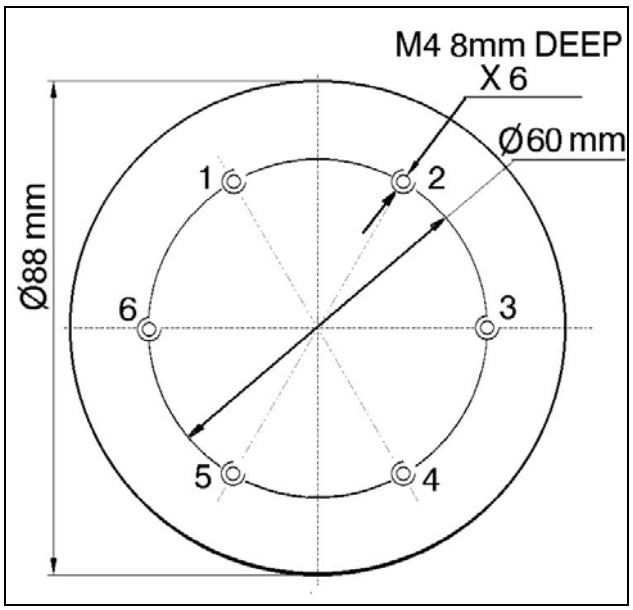

Figure 4-6: Gripper Mounting Flange Layout

1. Using a hex wrench and four M4x10 socket screws, attach the gripper to the robot arm flange.
2. Connect the coiled double hose from the gripper to the quick coupling on the robot's forearm, as indicated in Figure 4-11.

Figure 4-7: Pneumatic Gripper

Figure 4-8: SCORBOT-ER 9Pro with Pneumatic Gripper

3. Refer to Figure 4-12.
   - Connect the two transparent 1/4" O.D. hoses from the quick connectors at the back of the robot arm to the CYL ports on the pneumatic valve.
   - Connect a 5 bar/90 PSI air supply to the IN port on the valve.

4. Refer to Figure 4-9.

   Connect the valve to the controller's User Power Supply as follows:

   - Connect the black wire to a common terminal.
   - Connect the red wire to the normally open (NO) terminal of any unused relay output.

5. Connect 24VDC (in accordance with your valve's specification) to the common (C) terminal of the same relay output, as shown in Figure 4-9.

   Attach the valve to the controller or any other metallic surface by means of the valve's magnetic base.

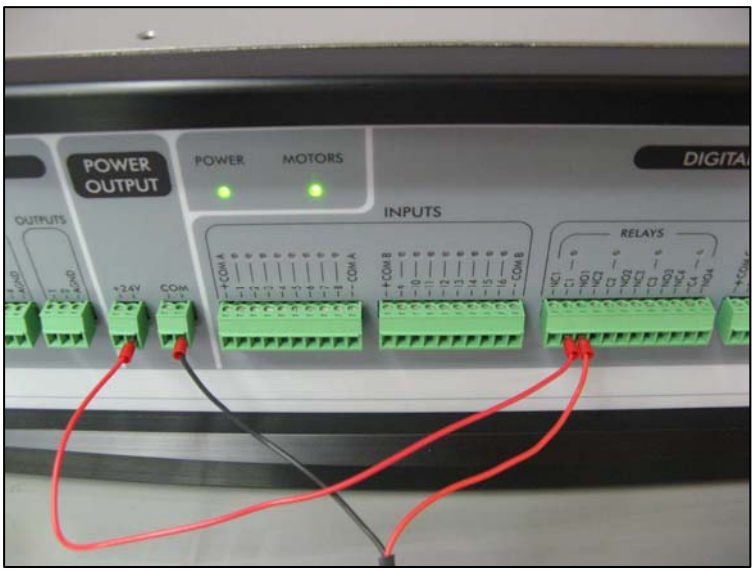

Figure 4-9: Example of gripper connection

Figure 4-10: Pneumatic gripper valve connection example (front connection)

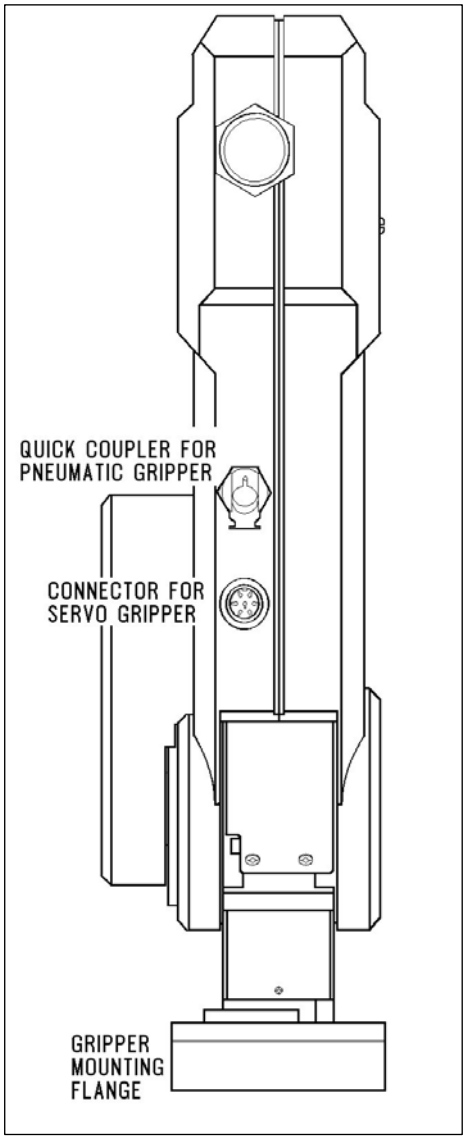

Figure 4-11: Gripper Connectors

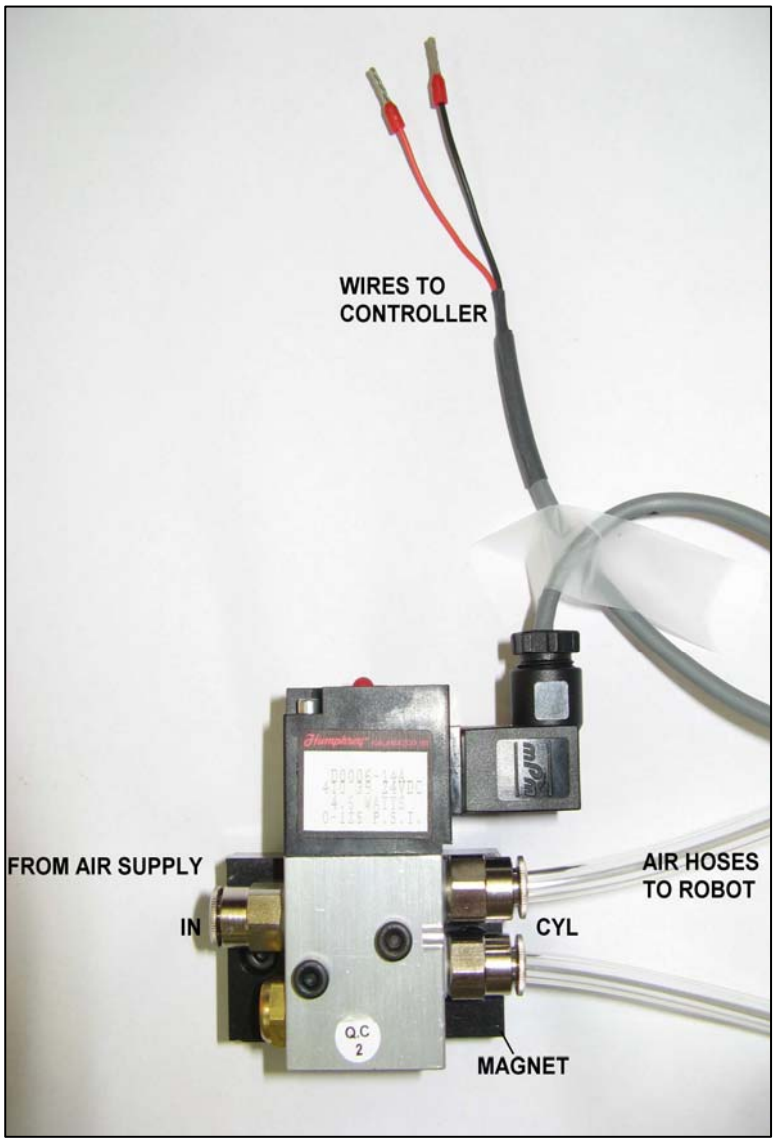

Figure 4-12: Pneumatic Solenoid Valve

DC Servo Gripper

The electric DC servo gripper is shown in the inset in Figure 4-13.

☞ *The robot must be homed before you mount the gripper.*

Refer to Figures 4-13 and 4-14.

1. Using a 3 mm hex wrench and four M4x10 socket screws, attach the gripper to the gripper mounting flange at the end of the robot arm.
2. Connect the gripper cable to the electrical connector on the robot arm.

   Make sure the connector is oriented as shown in Figure 4-13.
3. Make sure the gripper cable is positioned as shown in Figure 4-14.
4. Carefully execute the robot HOME command. Stay close to the teach pendant or controller. If the gripper cable becomes entangled or excessively stretched during the homing, abort the procedure immediately.
5. The gripper has a rotation of ±270°. Do not attempt to move the gripper beyond this limit.

6. At the end of each work session (before turning off the controller), or before homing the robot, make sure the gripper's position is as shown in Figure 4-14.

☞ *Axis 6 is reserved by default controller configuration for a servo gripper. To connect a different device as axis 6, you must change the system configuration by means of the Hardware Setup that is found under Options on the Menu Bar.*

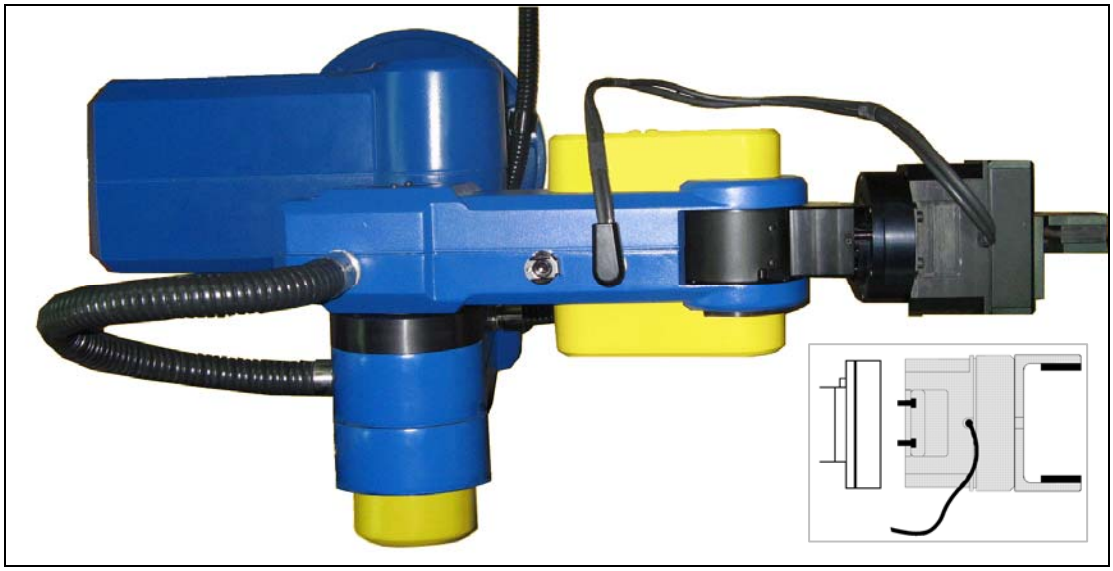

Figure 4-13: Connecting Gripper to SCORBOT-ER 9Pro

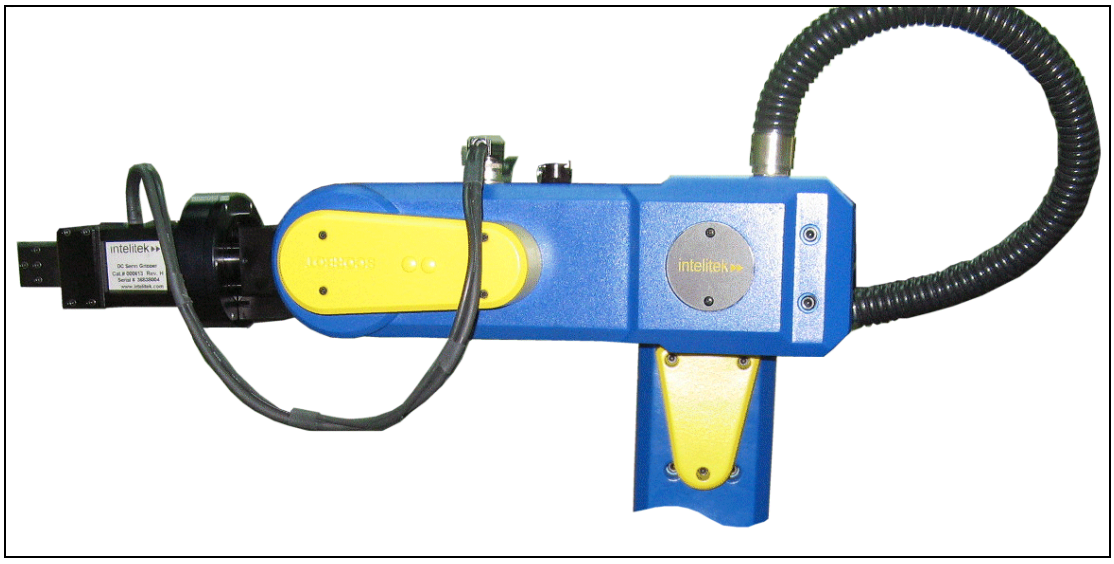

Figure 4-14: Connecting Gripper to SCORBOT-ER 9Pro

Activating the Gripper

Open and close the gripper in order to verify that it is functioning. To do so, select **View** | **Manual Movement**. Control the gripper using the manual movement window which appears. This window can be used for both the electric and the pneumatic gripper.

4

Operating Methods

The SCORBOT-ER 9Pro robot can be programmed and operated in two ways. The Scorbase for ER 9Pro/ER 14Pro User Manual includes instructions on operating the robot.

Software

Scorbase Software

Scorbase for ER 9Pro/ER 14Pro is a robot control software package which is supplied with the controller. Its menu-driven structure and off-line capabilities facilitate robotic programming and operation.

Scorbase runs on any PC system with Microsoft Windows XP/Vista/7, and communicates with the Controller through USB plug and play interface.

The Scorbase for ER 9Pro/ER 14Pro User Manual provides detailed descriptions and examples of the Scorbase commands.

Teach Pendant

The teach pendant is a hand-held terminal which is used for controlling the SCORBOT-ER 9Pro robot and peripheral equipment. The teach pendant is most practical for moving the axes, recording positions, and sending the axes to recorded positions. Other functions can also be executed from the teach pendant.

☞ *The Teach Pendant will only work if Scorbase is running on the PC, and is in On-line mode.*

The Teach Pendant for Controller USB-Pro User Manual fully describes the various elements and functions of the teach pendant.

5

Drive System

The three main elements of the SCORBOT-ER 9Pro drive system are shown in Figure 6-1:

- DC electrical motor
- Harmonic Drive gear
- Timing belt and pulleys

Figure 6-1 shows the drive system for axes 1 through 4 of the SCORBOT-ER 9Pro. The roll axis (axis 5) transmission does not contain the pulleys and timing belt; only a Harmonic Drive is used.

☞ *Note that the illustrations of components shown in this chapter are for descriptive purposes, and may not be the actual components used in the SCORBOT-ER 9Pro.*

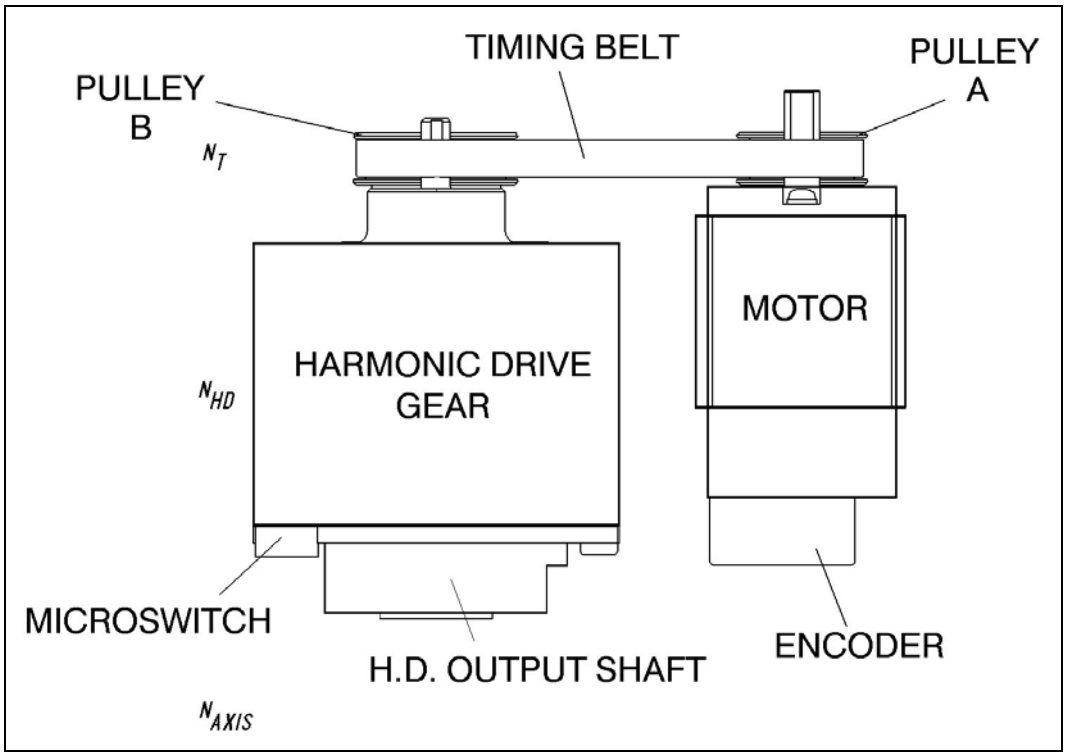

Figure 6-1: The SCORBOT-ER 9Pro Drive System

Motors

The SCORBOT-ER 9Pro robot arm is driven by DC electric motors. These actuators convert signals from the controller (electric power) into rotations of the motor shaft (mechanical power).

A robot arm such as the SCORBOT-ER 9Pro imposes severe requirements on the actuators, such as the following:

- The robot motor must rotate at different speeds, and with a high degree of accuracy. For example, if the robot is to be used for a spray painting application, it must be able to accurately follow the defined path at the specified speed.
- The robot motor must allow fine speed regulation so that the robot will accelerate and decelerate as required by the application.
- The robot motor must supply large torques throughout its speed range and also when the joint is stationary.
- The robot motor must be able to stop extremely quickly without overshooting the target position, and perform rapid changes in direction.
- Since mounting motors on the robot arm adds to the robot's weight and inertia, the robot motors must be light and compact, yet powerful. As shown in Figure 6-2, the motors of the SCORBOT-ER 9Pro are located on the axes they drive, with a two-stage (axes 14) or one-stage (axis 5) transmission.

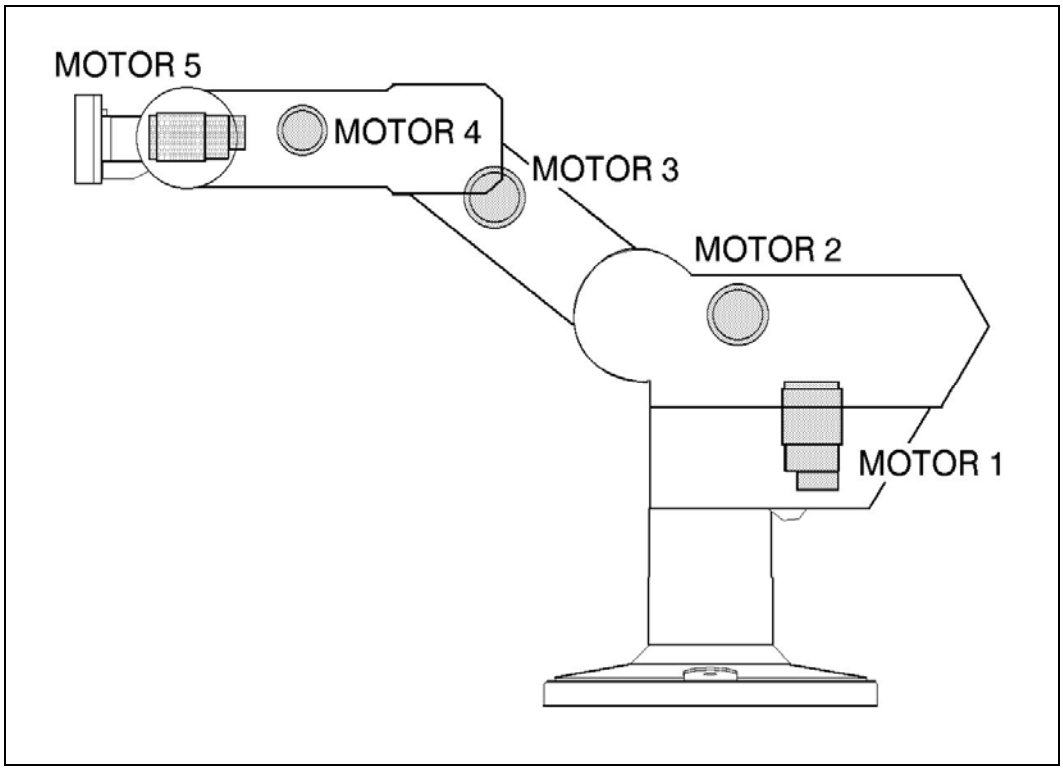

Figure 6-2: Motor Locations in SCORBOT-ER 9Pro

DC Motor Structure

The principles of operation of electrical motors in general, and DC motors in particular, are based on an electrical current flowing through a conductor situated within a magnetic field. This situation creates a force which acts on the conductor.

Figure 6-3 shows the basic structure and components of a DC motor comparable to the structure of the motors used in the SCORBOT-ER 9Pro. This motors has three main components:

- **Stator**: This is a static component which creates the magnetic field. The stator may be a permanent magnet, or an electromagnet consisting of a coil wound around thin iron plates.
- **Rotor**: This is the component which rotates within the magnetic field. The external load is connected to the rotor shaft. The rotor is generally composed of perforated iron plates, and a conducting wire is wound several times around the plates and through the perforations. The two ends of the conductor are connected to the two halves of the commutator, which are connected to the electric current via the brushes.
- **Brushes**: These connect the rotating commutator to the electric current source.

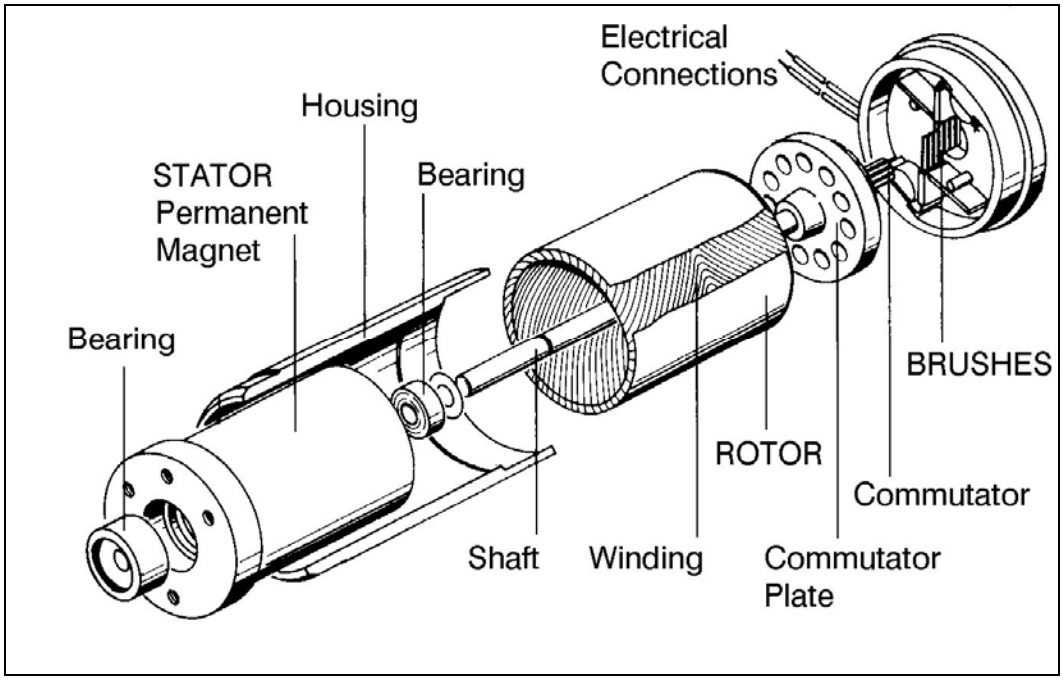

Figure 6-3: Basic Structure of a DC Motor

SCORBOT-ER 9Pro Motors

The SCORBOT-ER 9Pro uses permanent magnet DC motors to drive the axes.

Axes 1, 2 and 3 of the SCORBOT-ER 9Pro are powered by the motor shown in Figure 6-4. Axes 4 and 5 are powered by the motor shown in Figure 6-5.

These motors are able to move at extremely high rates of revolution, to move loads with high torques, and (with encoder attached) to achieve a very high resolution.

Table 6-1: Motor Specifications

	Motor Axes 1, 2, 3	**Motor Axes 4, 5**
Peak Rated Torque	143 oz.in	27.8 oz.in
Rated Torque	32 oz.in	12.5 oz.in
Maximum Operating Speed	4000rpm	4500rpm
Weight	1.29k / 2.84lb	0.28k / 0.62lb

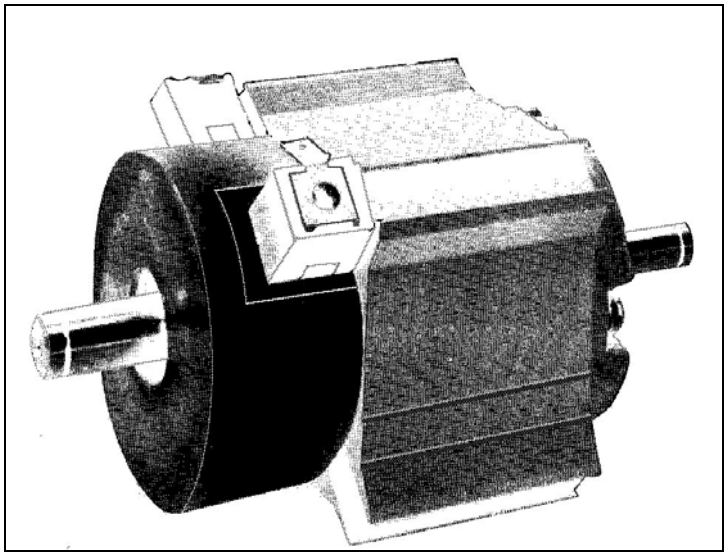

Figure 6-4: Motor on Axes 1, 2 and 3

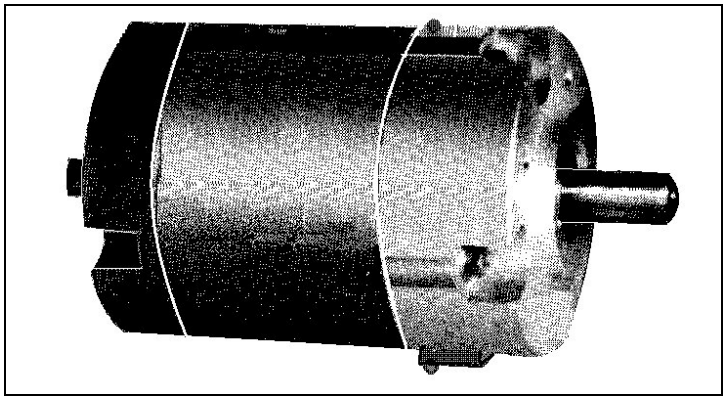

Figure 6-5: Motor on Axes 4 and 5

Harmonic Drive Gears

The Harmonic Drive transmission used in the SCORBOT-ER 9Pro, shown in Figure 6-6, offers a very high gear ratio.

The Harmonic Drive gears used in the SCORBOT-ER 9Pro have four main components:

- **Circular spline:** a solid steel ring, with internal gear teeth, usually fixed to the robot link.
- **Wave generator:** a slightly elliptical rigid disk, which is connected to the input shaft, with a ball bearing mounted on the outer side of the disk.
- **Flexspline:** a flexible, thin-walled cylinder, with external gear teeth, usually connected to the output shaft.
- **Dynamic spline:** a solid steel cylinder, with internal gear teeth.

The external gear teeth on the flexspline are almost the same size as the internal gear teeth on the circular spline except there are two more teeth on the circular spline, and the teeth only mesh when the wave generator pushes the flexspline outwards.

Because the wave generator is elliptical, the flexspline is pushed out in two places. As the motor rotates the input shaft, the wave generator rotates and the location of meshing teeth rotates with it. However, because there are two less teeth on the flexspline, it has to rotate backwards slightly as the wave generator rotates forwards. For each complete rotation of the input shaft, the flexspline moves backwards by two teeth. Figures 6-7 and 6-8 show the different steps in this process.

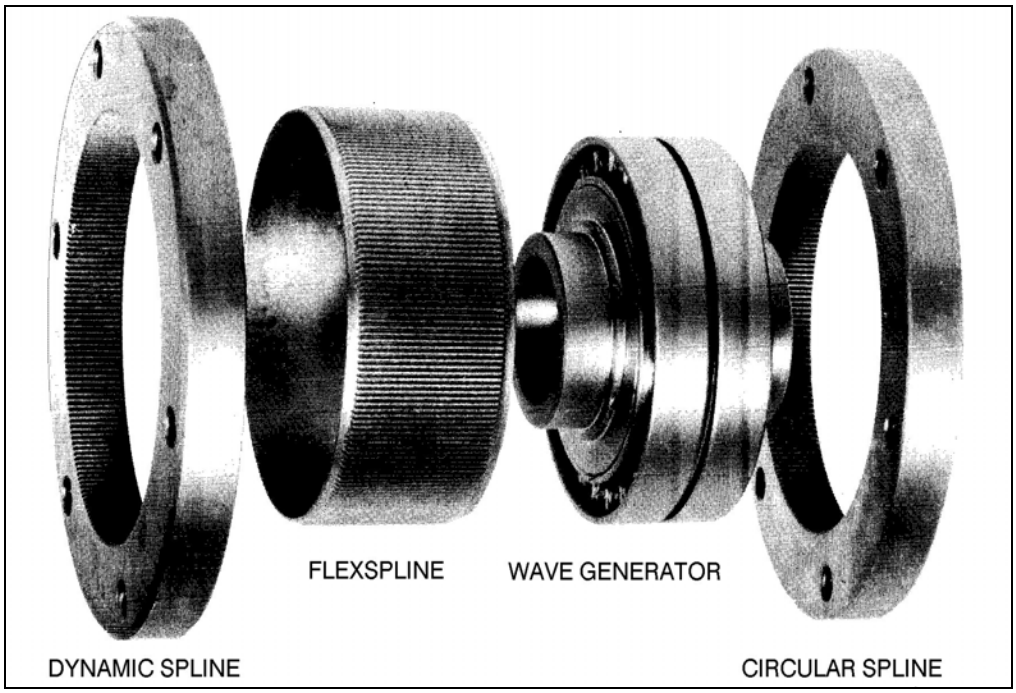

Figure 6-6: Harmonic Drive Structure

Harmonic Drive Gear Ratios

As in all gears, the gear ratio of the Harmonic Drive is the ratio of the input speed to the output speed. If the number of teeth on the flexspline is N_f, then for every revolution of the input shaft, the output shaft rotates by $2/N_f$ of a revolution (that is, two teeth out of N_f teeth). Hence:

$$\text{HD gear ratio} = \frac{1}{\left(\frac{2}{Nf}\right)} = \frac{Nf}{2}$$

The Harmonic Drive gear ratios for each of the SCORBOT-ER 9Pro axes are as follows:

Axis 1 – 160:1

Axis 2 – 160:1

Axis 3 – 160:1

Axis 4 – 100:1

Axis 5 – 100:1

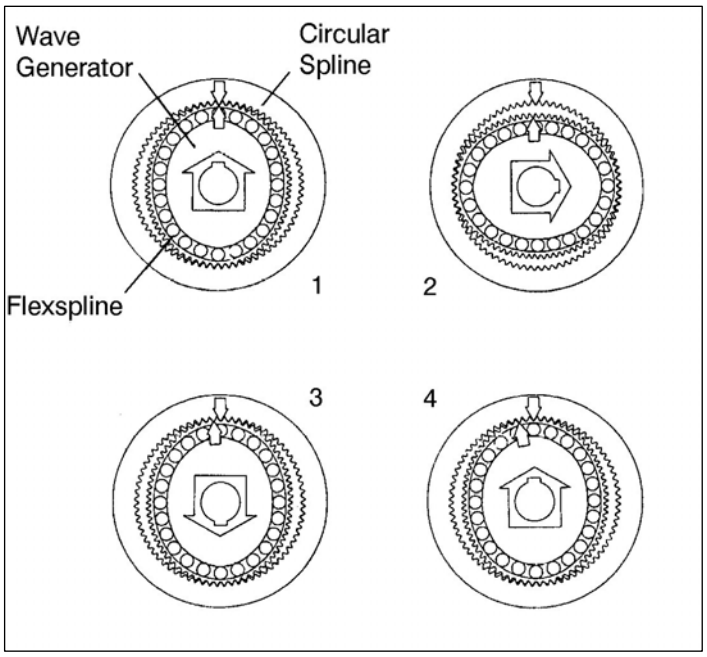

Figure 6-7: Operation of the Harmonic Drive

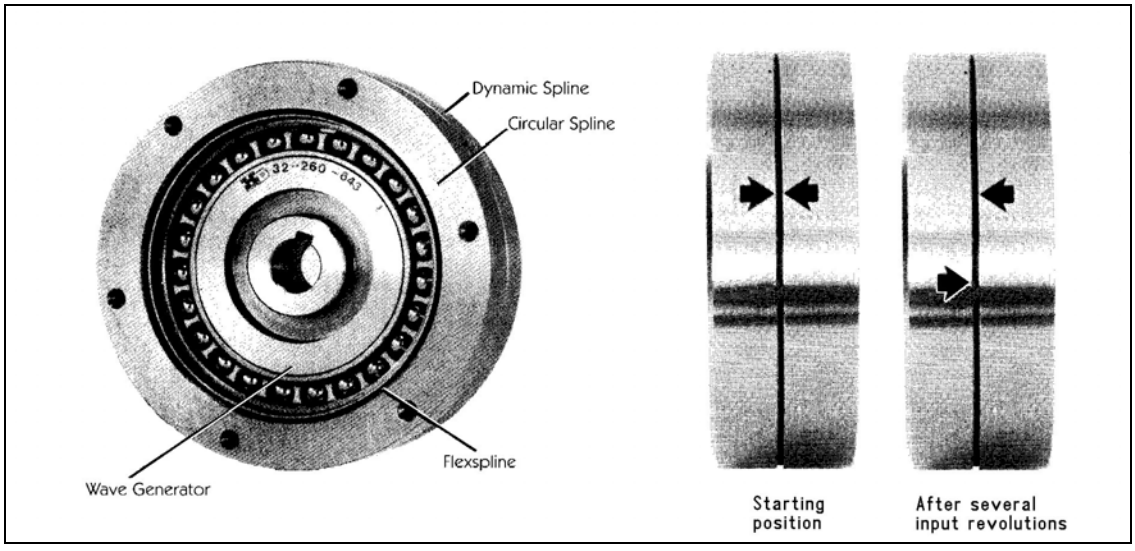

Figure 6-8: Operation of the Harmonic Drive

Axis Gear Ratios

Referring again to Figure 6-1, the transmission of axes 1 through 4 consists of two stages: the timing belt drive, and the Harmonic Drive.

The overall gear ratio of the output shaft which moves the axis is therefore expressed as:

$$N_T \times N_{HD} = N_{AXIS}$$

Where:

N_T is the belt drive ratio (that is, the radii ratio): $\frac{PulleyB}{PulleyA}$

N_{HD} is the Harmonic drive ratio, as described above.

N_{AXIS} is the overall gear ratio of the axis.

Table 6-2: SCORBOT-ER 9Pro Gear Ratios

	N_T	N_{HD}	N_{AXIS}
Axis 1	1.33 : 1	160 : 1	213.33 : 1
Axis 2	1.52 : 1	160 : 1	243.8 : 1
Axis 3	1.33 : 1	160 : 1	213.33 : 1
Axis 4	1.8 : 1	100 : 1	180 : 1
Axis 5		100 : 1	100 : 1

Thus, one rotation (360) of axis 3, for example, requires 213.33 rotations of the motor shaft. The actual movement of the axis, however, is limited by the arm's mechanical structure.

6

Position and Limit Devices

This chapter describes the various elements in the SCORBOT-ER 9Pro which play a part in the positioning of the robot arm and the limiting of its motion.

- Encoders
- End of Travel Switches
- Hard Stops
- Home Switches

Encoders

The location and movement of each SCORBOT-ER 9Pro axis is measured by an electro-optical encoder attached to the motor which drives the axis. The encoder translates the rotary motion of the motor shaft into a digital signal understood by the controller.

Figure7-1 shows the encoder mounted on a SCORBOT-ER 9Pro motor.

The encoder used on the SCORBOT-ER 9Pro contains a single light emitting diode (LED) as its light source. Opposite the LED is a light detector integrated circuit. This IC contains several sets of photodetectors and the circuitry for producing a digital signal. A perforated, rotating disk is located between the emitter and detector IC.

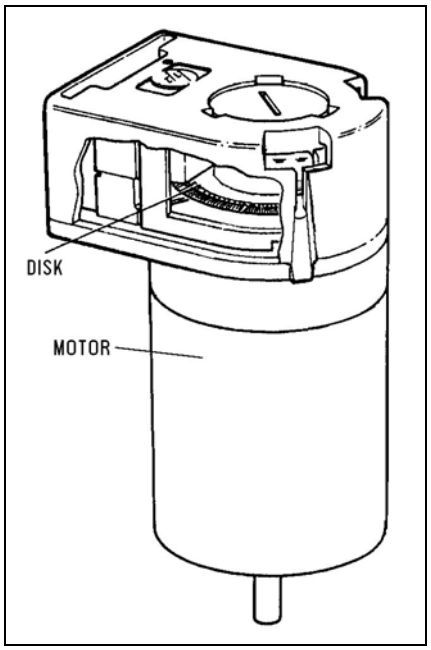

Figure 7-1 SCORBOT-ER 9Pro Encoder

As the encoder disk rotates between the emitter and detectors, the light beam is interrupted by the pattern of bars and windows on the disk, resulting in a series of pulses received by the detectors.

The SCORBOT-ER 9Pro encoders have 512 slots, as shown in Figure 7-2. An additional slot on the encoder disk is used to generate an index pulse (C-pulse) once for each full rotation of the disk. This index pulse serves to determine the home position of the axis.

The photodetectors are arranged so that, alternately, some detect light while others do not. The photodiode outputs are then fed through the signal processing circuitry, resulting in the signals A, A, B, B, I and I, as shown in Figure7-3.

Comparators receive these signals and produce the final digital outputs for channels A, B and I. The output of channel A is in quadrature with that of channel B (90 out of phase), as shown in Figure 7-4. The final output of channel I is an index pulse.

When the disk rotation is counterclockwise (as viewed from the encoder end of the motor), channel A will lead channel B. When the disk rotation is clockwise, channel B will lead channel A.

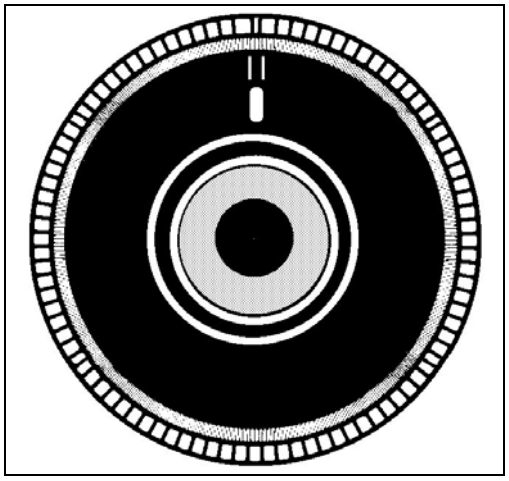

Figure 7-2 SCORBOT-ER 9Pro Encoder Disk

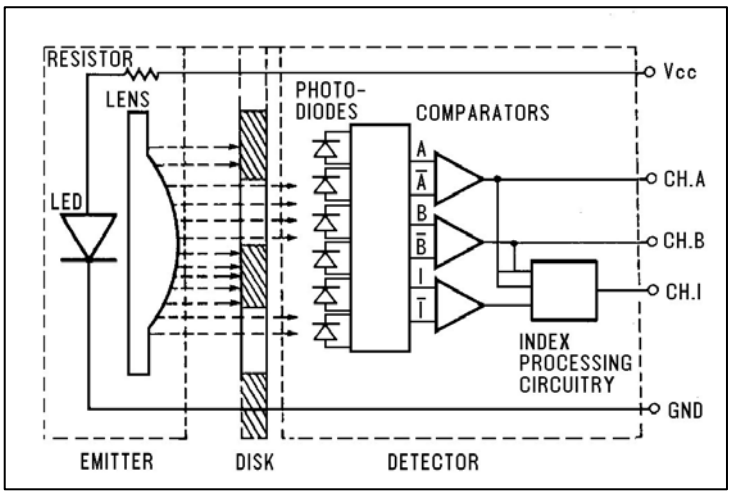

Figure 7-3: Encoder Circuitry

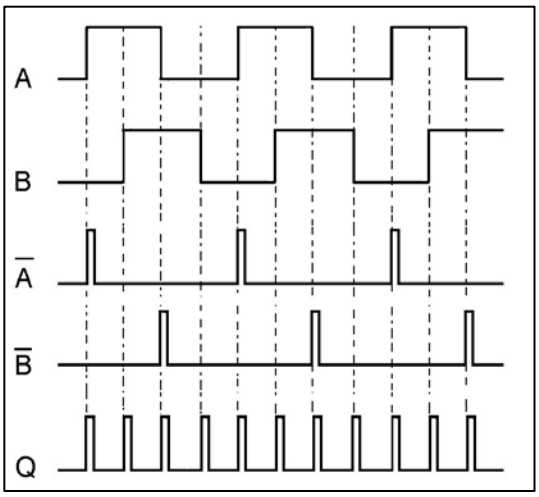

Figure 7-4: Encoder Output Signals

Encoder Resolution

From the quadrature signal the Controller USB-Pro measures four counts for each encoder slot, thus quadrupling the effective resolution of the encoder.
The resolution of the encoder is expressed as:

$$S_E = \frac{360°}{n}$$

Where:

S_E is the resolution of the encoder.

n is the number of counts per encoder revolution.

The encoders used in the SCORBOT-ER 9Pro have 512 slots, generating 2048 counts per motor revolution. The encoder resolution is therefore:

$$S_E = \frac{360°}{2048} = .176°$$

When the encoder resolution is divided by the overall gear ratio of the axis, the resolution of the joint is obtained.

Since the encoder is mounted on the motor shaft, and turns along with it, the resolution of the joint is expressed as:

$$S_{JOINT} = \frac{S_E}{N_{AXIS}}$$

Thus, for example, the resolution of joint 3 of the SCORBOT-ER 9Pro is therefore as follows:

$$S_{J3} = \frac{0.176°}{213.33} = 0.000825°$$

The resolution is the smallest possible increment which the control system can identify and theoretically control. The accuracy of the axis that is, the precision with which it is positioned is affected by such factors as backlash, mechanical flexibility, and control variations.

End of Travel (Limit) Switches

The **SCORBOT-ER 9Pro** uses limit switches to prevent the joints from moving beyond their functional limits. When a control error fails to stop the axis at the end of its working range, the limit switch serves to halt its movement. The switch is part of an electric circuit within the robot arm, independent of the robot controller.

The limit switches used in the SCORBOT-ER 9Pro are shown in Figure 7-5.

Each of axes 1 through 4 has two limit switches: one at each end of the axis' working range.

Axis 5 (roll) has no travel limit switches; it can rotate endlessly. When a gripper is attached to axis 5, its movements are controlled and limited by means of software only (encoder).

The limit switches are mounted on a disk which is attached to the robot's frame. The disk for axis3 is shown in Figure 7-6.

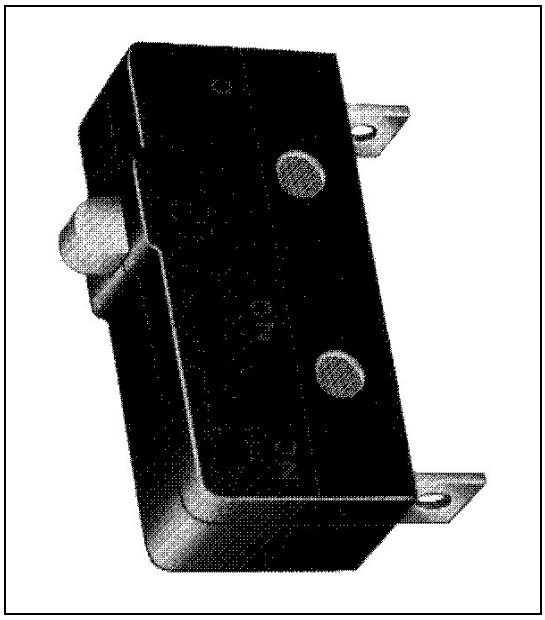

Figure 7-5: SCORBOT-ER 9Pro Limit Switch

The output shaft of the Harmonic Drive moves relative to the microswitch disk.

As the joint moves, a cam on the Harmonic Drive output shaft reaches a point at which it forces the actuating button of the limit switch into a position which activates the switch.

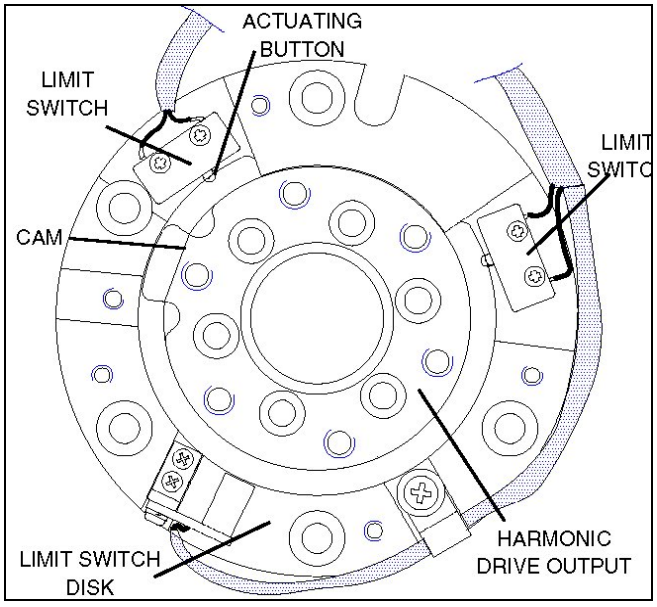

Figure 7-6: Limit Switch Activation

When the limit switch is activated, it causes a control error, resulting in the activation of COFF (control off mode), and an impact protection message.

CON (control on mode) must be activated and the robot arm must be manually moved (using Scorbase or a teach pendant) away from the impact condition.

Hard Stops

When the software limits and/or the end of travel switches fail to halt the movement of the robot arm, it is possible that the momentum of the robot arm will drive it until it reaches its mechanical limit.

When the joint reaches this hard stop, the impact protection and thermic protection processes detect an error, thus activating COFF.

CON must be activated and the robot arm must be manually moved away from the impact condition.

Home Switches

The SCORBOT-ER 9Pro uses an optical home switch on each axis to identify the fixed reference, or home, position.

The home switch is mounted on the same disk as the end of travel switches, and a flag is attached to the Harmonic Drive output shaft,
as shown in Figure 7-7.

During the homing procedure, the robot joints are moved, one at a time. Each axis is moved until the flag cuts the beam of light. When that occurs, the optical detector on each joint sends a specific signal to the controller.

Once the home switch location has been detected, the axis motor continues to rotate until its encoder produces an index pulse. The point at which that occurs is the axis home position.

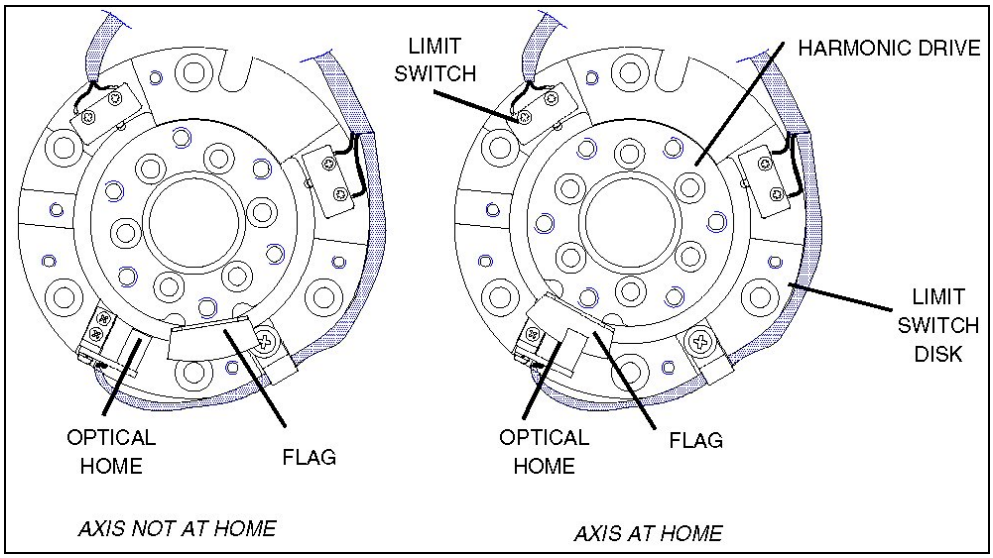

Figure 7-7: Home Switch Activation

7

Wiring

Figure 8-1 is a schematic diagram of the SCORBOT-ER 9Pro cable connections. The wire braid which connects the robot to the controller contains a power (robot) cable and an encoder cable.

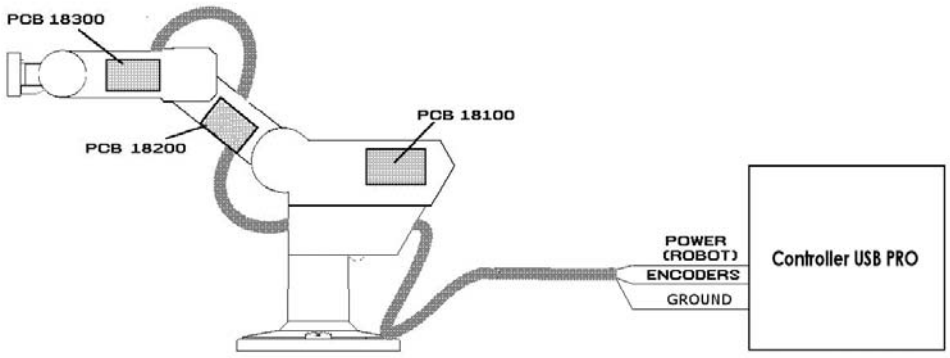

Figure 8-1: SCORBOT-ER 9Pro Cabling

The body, upper arm and forearm links each contain a printed circuit board (PCB). The motors, encoders, limit switches and home switches for each axis are directly connected to one of these three internal PCBs. Two wire braids connect the PCBs. Each PCB transfers power to the motors to which it is directly connected, and receives signals from the corresponding limit and home switches. When a limit switch is triggered, the PCB automatically cuts off power to the motor that drives the axis. In addition, each PCB transfers power to the next
PCB and sends encoder and home switch signals to the previous PCB.

The robot and encoder cables are directly connected to PCB 18100. The robot cable supplies power to the PCB and the encoder cable carries information from the encoders and the home switches for all six axes to the controller.

Robot (Power) Cable and Connector

Figure 8-2 shows the D-SUB 50 male connector that joins the power cable to the controller's back panel.

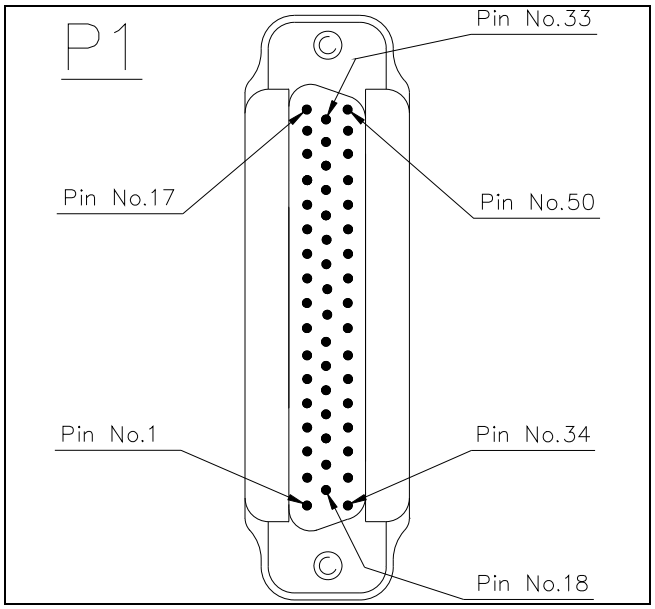

Figure 8-2: D50 Connector

The robot cable contains 14 leads. The following table details the connector pin functions and cable wiring.

Table 8-1: Robot (Power) Cable and Wiring Connector

Pin No.	Pin Description Robot Side (J1)	Belden Wire Color	Pin Description Controller Side (P1)
1, 2	Motor 1 +	Black	M0_A
19, 20	Motor 1 -	Red	M0_B
36, 37	Motor 2 -	Brown	M1_A
5, 6	Motor 2 +	Orange	M1_B
23, 24	Motor 3 -	Yellow	M2_A
40, 41	Motor 3 +	Purple	M2_B
9, 10	Motor 4 -	Light blue	M3_A
27, 28	Motor 4 +	Blue	M3_B
44, 45	Motor 5 -	Grey	M4_A
13, 14	Motor 5 +	Pink	M4_B
31, 32	Motor 6 -	White	M5_A
48, 49	Motor 6+	Green	M5_B

Pin No.	Pin Description Robot Side (J1)	Belden Wire Color	Pin Description Controller Side (P1)
50	+24VDC	Red	+24VDC
17	24VDC RET	Black	24V RET

Encoder Cable and Connector

The encoder cable, which connects the controller to the motor encoders and optical home switches, contains 36 leads.

Figure 8-3 shows the D37 female connector that joins the encoder cable to the controller's back panel.
The following table details the connector pin functions and describes the cable wiring.

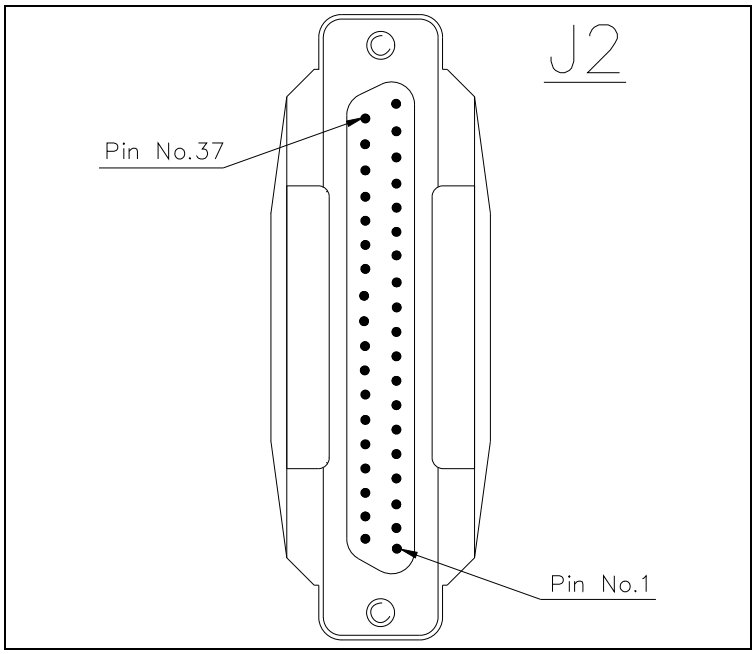

Figure 8-3: D37 Connector

Table 8-2: Encoder Cable and D37 Connector

Pin ID	Signal Name, Robot Side (J1)	Axis	Telephone Cable Wires Color	Signal Name, Controller Side (J2)
1	+5V	1	red	+5V
8	COMMON		yellow	COMMON 0
5	CHA1 (Encoder Pulse A)		green	CHA 0
6	CHB1 (Encoder Pulse B)		white	CHB 0
7	CHC1(Encoder Index Pulse)		black	CHC 0
31	MSWITCH (Home Switch)		blue	MSWITCH
1	+5V	2	red	+5V
12	COMMON		yellow	COMMON 1
9	CHA2 (Encoder Pulse A)		green	CHA 1
10	CHB2 (Encoder Pulse B)		white	CHB 1
11	CHC2 (Encoder Index Pulse)		black	CHC 1
32	MSWITCH (Home Switch)		blue	MSWITCH

Pin ID	Pin Description Robot Side (J1)	Axis	Telephone Cable Color	Pin Description Controller Side (J2)
1	+5V	3	red	+5V
16	COMMON		yellow	COMMON 2
13	CHA3 (Encoder Pulse A)		green	CHA 2
14	CHB3 (Encoder Pulse B)		white	CHB 2
15	CHC3 (Encoder Index Pulse)		black	CHC 2
33	MSWITCH (Home Switch)		blue	MSWITCH
2	+5V	4	red	+5V
20	COMMON		yellow	COMMON 3
17	CHA4 (Encoder Pulse A)		green	CHA 3
18	CHB4 (Encoder Pulse B)		white	CHB 3
19	CHC4 (Encoder Index Pulse)		black	CHC 3
34	MSWITCH (Home Switch)		blue	MSWITCH
2	+5V	5	red	+5V
24	COMMON		yellow	COMMON 4
21	CHA5 (Encoder Pulse A)		green	CHA 4
22	CHB5 (Encoder Pulse B)		white	CHB 4
23	CHC5 (Encoder Index Pulse)		black	CHC 4
35	MSWITCH (Home Switch)		blue	MSWITCH
2	+5V	6	red	+5V
28	COMMON		yellow	COMMON 5
25	CHA6 (Encoder Pulse A)		green	CHA 5
26	CHB6 (Encoder Pulse B)		white	CHB 5
27	CHC6 (Encoder Index Pulse)		black	CHC 5
36	MSWITCH (Home Switch)		blue	MSWITCH
37	Internal jumper to pin 16 to detect when the cable is disconnected			

8

Maintenance

The maintenance and inspection procedures recommended below will ensure the best possible performance of the robot over an extended period.

Daily Operation

At the start of each working session, check the robot and controller, in the following order:

1. Before you power on the system, check the following items:
   - The installation meets all safety standards.
   - All cables are properly and securely connected.
   - Cable connector screws are fastened.
   - The gripper is properly connected.
   - The air supply (for a pneumatic gripper) is functioning properly.
   - Any peripheral devices or accessories which will be used, such as the teach pendant or a remote EMERGENCY button, are properly connected to the controller.
2. After you have powered on the system, check the following items:
   - No unusual noises are heard.
   - No unusual vibrations are observed in any of the robot axes.
   - There are no obstacles in the robot's working range.
3. Bring the robot to a position near home, and activate the Home procedure. Check the following items:
   - Robot movement is normal.
   - No unusual noise is heard when robot arm moves.
   - Robot reaches home position in every axis.

Periodic Inspection

The following inspections should be performed regularly:

- Check robot mounting bolts for looseness using a wrench. Retighten as needed.
- Check all visible bolts and screws for looseness using a wrench and screwdriver. Retighten as needed.
- Check cables. Replace if any damage is evident.

The following robot components may require replacing after prolonged use of the robotic arm causes them to wear or fail:

- DC Servo Motors
- Motor Brushes
- Timing Belts
- V-Rings
- Harmonic Drives
- Cross-Roller Bearings

Troubleshooting

Whenever you encounter a problem with your system, try to pinpoint its source by exchanging the suspected faulty component for example, robot, controller, teach pendant, cable with one from a functioning system.

In general, when trying to determine the source of a malfunction, first check the power source and external hardware, such as controller switches, LEDs and cable connections. Then check fuses; you may also open the controller to check components, according to the procedures and instructions detailed in the Controller USB-Pro User Manual.

In addition, make sure the controller is properly configured for the robot and gripper, the software commands have been correctly issued, and system parameters are properly set.

All troubleshooting procedures described in the section can be performed by the user.

☞ *Do not attempt to open the robot arm. There are no user-serviceable parts inside.*

☞ *Do not alter Scorbase system parameters*

If you are unable to determine and/or correct the problem, contact your service representative. Only qualified technicians may remove and/or replace robot components.

1. Controller functioning, but the robot cannot be activated.

- Make sure Scorbase is in Online Mode. Select **Options | On-line** from the Menu bar.
- Make sure an obstacle is not blocking the robot.
- Make sure the green Motors LED is lit.
- Make sure the controller is in the control off (COFF) state. Then activate the control on (CON) state from the PC or TP.
- Make sure all robot and encoder cables are properly connected.

2. *Robot does not find Home position in one or all of the axes.*

- Make sure the homing command was properly issued.
- Make sure all robot and encoder cables are properly connected.
- Make sure Scorbase is correctly configured. Refer to the Scorbase for ER 9Pro/ ER 14Pro User Manual.
- Make sure system homing parameters are properly set. Refer to the Scorbase for ER 9Pro/ER 14Pro User Manual.
- Check whether the optical home switch for this axis is functioning.

To do this:

1. Select **View | Movement Information.**
2. Physically move each axis in the two directions in which it moves while watching the Movement Information window. The area in which the axis value in Home Switch reads “0” is the axis’ Home area. Where the value is “1” is outside it’s Home area.

   If the axis’ value in the **Movement Information** window does not change, possible causes are:

   - Faulty arm circuitry.
   - Faulty optical switch; optical switch not properly mounted.
   - Faulty driver circuitry

3. *One of the axes does not function.*

- Check the axis' fuse on the rear panel of the Controller.
- Check the encoder:

Select **View | Dialog Bars | Encoder Counts** to display the encoder readings.

Click the **Control Off**

icon (to disable servo control) and then physically move the axis in question in both directions.
The encoder reading should rise for rotation in one direction and fall for rotation in the opposite direction. If this does not occur, there is a problem in the encoder or its circuitry.
If the encoder readings do not change, check whether the encoder connector is properly connected to the rear controller panel.
The problem may be caused by faulty encoder connectors on the robot's internal PCB's.

4. *Errors in the repeatability of the robot.*

- Try to identify the faulty axis. If many or all axes are faulty, look for an electrical noise source in your environment.
- Check the controller's ground and the robot's ground connection to the safety ground terminal at the back of the controller.
- Check the encoder.

Bring the robot to a starting position. Using a pencil, draw a fine, continuous line on the robot which crosses from the cover of one link to the cover of the adjacent link at the joint in question.
Select **View | Dialog Bars | Encoder Counts** to display the encoder readings.

Click the **Control Off**

icon (to disable servo control) and then physically move the axis in question to another position. Then return to the starting position marked by the line you drew. Check the encoder reading for the axis again. It should be within 5 counts of the previous reading; if not, the encoder needs to be replaced.

☞ *Note for more precision in repeatability always start from the same position when moving to a specific location. Thus wherever the axis in question is located, always move to the end point via the same specific position.*

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5. Unusual noise.

- Loose screws.
- Poor lubrication.
- Ratcheting.
- Worn motor brushes.
- Worn timing belt.
- Damaged harmonic drive.

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6. Unusual smell.

- A motor or an internal PCB has burnt out and needs to be replaced.

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7. Axis/axes vibrating, too weak to carry load, motion not smooth, or jerks during or at end of motion.

- System parameters are not properly adjusted.

Refer to the Scorbase for ER 9Pro/ER 14Pro User Manual.

- Problem in axis driver card(s) in the controller.

Refer to the Controller USB-Pro User Manual.

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8. Pneumatic gripper does not respond.

- Check that all air hoses are connected properly.
- Make sure the gripper is connected to the proper controller output.
- Check the relay output to which the gripper is connected.
- Check whether the relays have been switched (LED is lit):
- When an output is in OFF state, NC contact is shorted to COM, and NO contact is disconnected from COM.

- When an output is in ON state, NO contact is shorted to COM, and NC contact is disconnected from COM.
- Check gripper configuration hardware setup. select **Options | Hardware Setup**.

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9. Error Messages

- For details on error messages refer to the System Messages chapter in the Scorbase for ER 9Pro/ER 14Pro User Manual.